Long-term monitoring of the glaciers in Wordie Bay, Antarctic Peninsula, using multi-mission SAR time series

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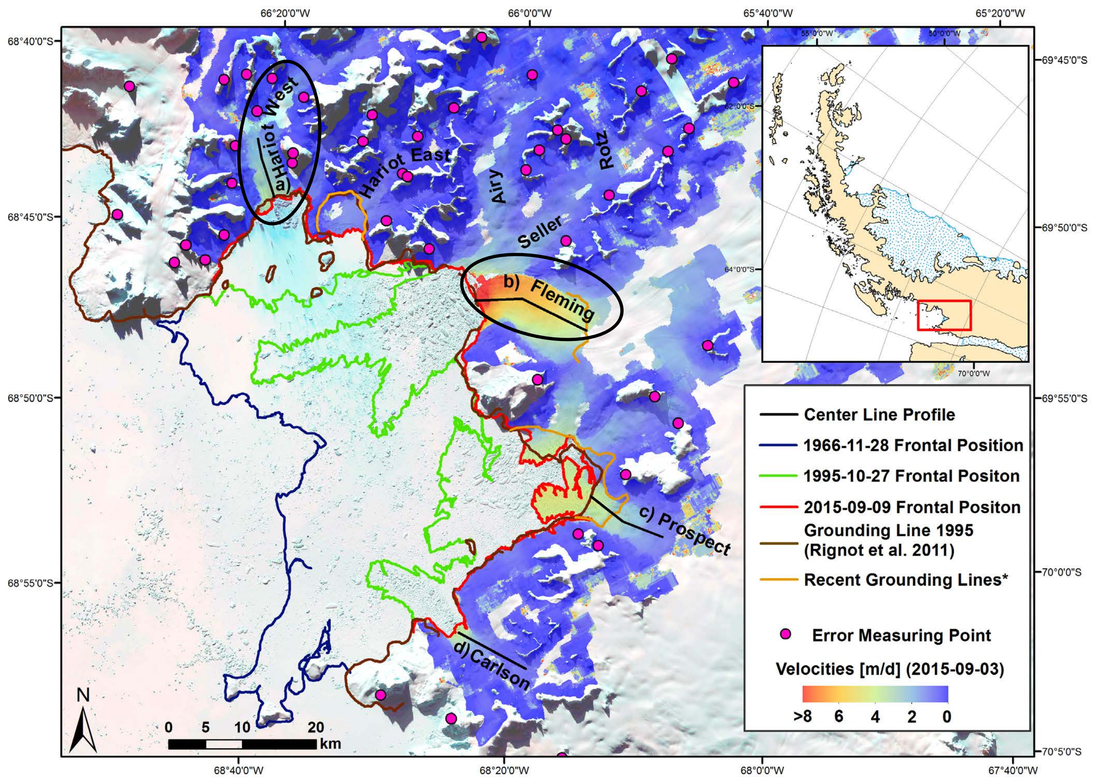
(1) MOTIVATION & RESEARCH QUESTIONS

- Disintegration of Wordie Ice Shelf since the 1970s in a series of events **(Fig. 2)**, acceleration and dynamic thinning of Fleming Glacier (Rignot et al. 2005, Wendt et al. 2010)
- No long-term studies which address the adaption process of the former tributary glaciers to the loss of the buttressing ice shelf
- How can multi-mission SAR data be used in order to derive long time series of datasets of glaciological parameters (e.g. velocities, ice elevation, mass balances,…) at Wordie Bay?
- How did these parameters change after the disintegration of the ice shelf exactly over time and how long do these changes last?
- Are there differences in the behavior of the single glaciers?

(3) PRIMARY DATASETS AND METHODS

Data	Data Type	Methods
ERS 1/2 (1994 – 2011)	C-Band SAR	Intensity Tracking
ALOS PALSAR (2006 – 2010)	L-Band SAR	Intensity Tracking
TSX / TDX (2010 – 2015)	X-Band SAR	Intensity Tracking Differential Range Direction Offset Tracking Interferometric DEM Differencing
ENVISAT (2006 – 2010)	C-Band SAR	Intensity Tracking
Sentinel-1 (2015 - 2016)	C-Band SAR	Intensity Tracking
Ice Bridge MCoRDS (2010 – 2011)	Ice Thickness	Buoyancy Calculations
Ice Bridge ATM (2004)	Laser Altimeter	Elevation Change
CECS Airborne Mapping System (CAMS) (2008)	Laser Altimeter	Elevation Change

(2) OVERVIEW OF THE STUDY AREA



Surface velocities from Sentinel-1 acquisitions (2015/08/28 and 2015/09/09).

Points of velocity error measurements are located on stable ground (e.g. bare rocks).

Background image: mosaic of Landsat-8 LandsatLook „Natural Color“ images from 2015/09/16 ©USGS

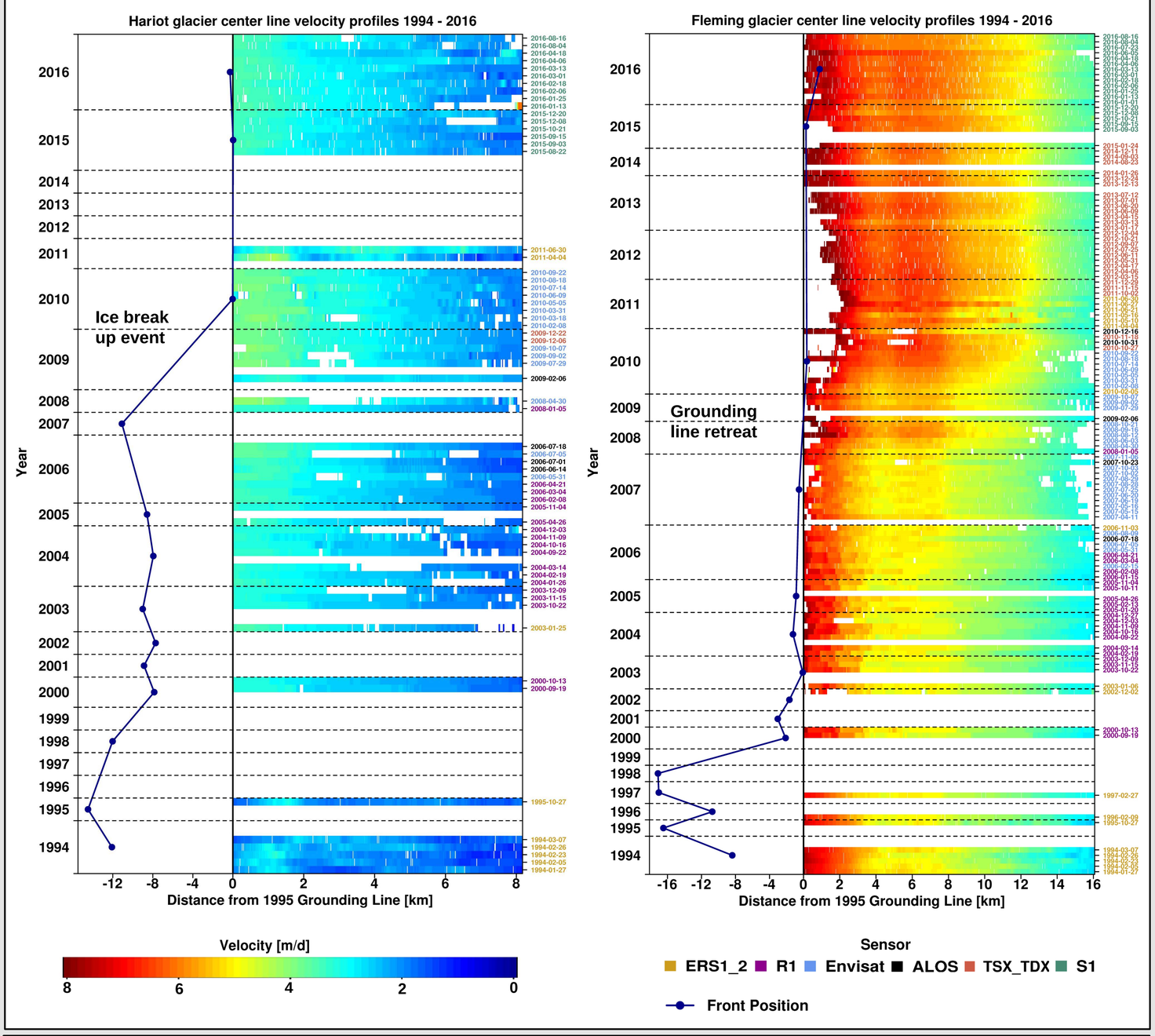
***Recent grounding lines:**

Hariot East glacier: from differential range direction offset tracking (range velocity fields from TSX-TDX acquisitions taken between March and July 2012 , rel. orbit 44)

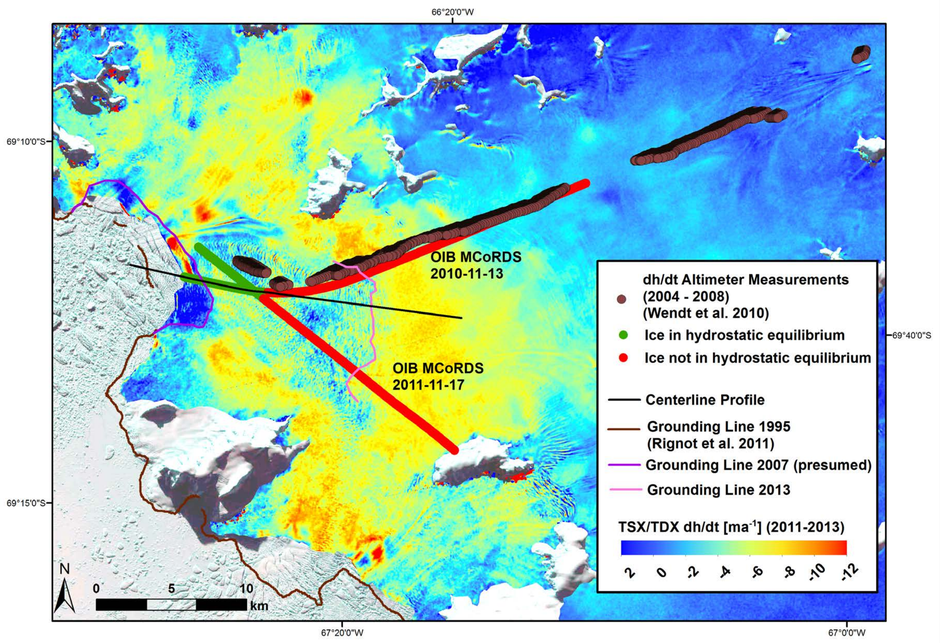
Fleming glacier: from elevation change measurements, velocity time series and buoyancy calculations **(see Section 5)**

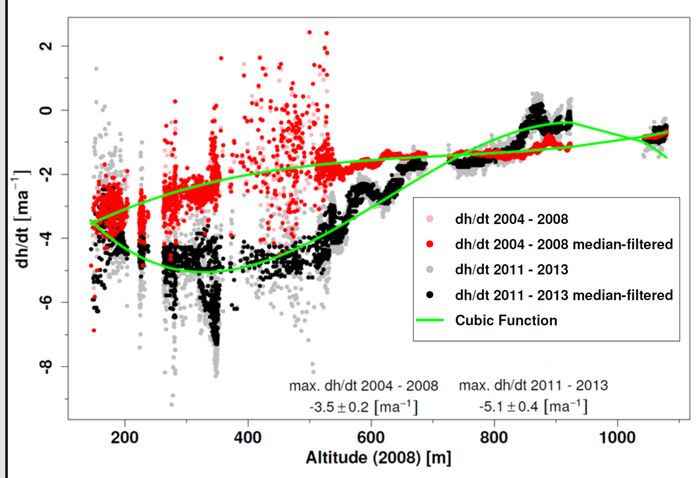
Prospect glacier: break in surface slope from Landsat-8 acquisition (2015/09/16)

(4) FLEMING AND HARIOT WEST GLACIER: CENTER LINE VELOCITY TIME SERIES 1995 – 2016



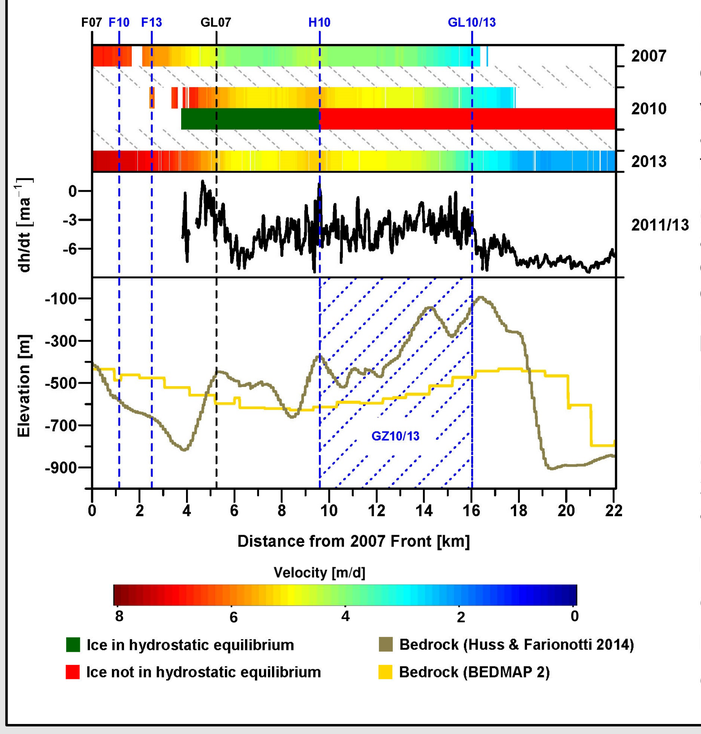
(5) FLEMING GLACIER: ELEVATION CHANGE AND GROUNDING LINE RECONSTRUCTION





a) Elevation change rates on Fleming glacier as a function of altitude, derived from altimeter measurements (2004/2008) (Wendt et al. 2010) and TSX/TDX-DEM differencing (2011/2013)

Data points of the differential DEM are extracted along the ATM 2004/CAMS 2008 profile (brown dots in the map above)



b) Rapid grounding line retreat at Fleming glacier

Velocity prior to (2007) and after (2010, 1013) the grounding line retreat, elevation change (TSX/TDX 2011 – 2013) and bedrock data are extracted along the center line profile shown in the map above (black line)

Floating condition of the ice is derived from buoyancy calculations (OIB MCoRDS Profile 2010-11-13 in the map above)

F: Front
GL: Grounding Line
H: Hydrostatic Point
GZ: Grounding Zone

(6) SUMMARY OF RESULTS

- After the complete loss of the buttressing ice shelf **(see Map 2)** and a subsequent acceleration, the **flow speeds of Fleming glacier remained stable until 2008 (see Fig. 4, right).** Therefore in earlier publications it was suggested that the glacier is approaching a new equilibrium.
- With the help of our dense multi-sensor velocity time series we could show that In the end of 2008 **a sudden acceleration of Fleming glacier and a strong upstream propagation of high velocities** took place **(see Fig. 4, right).** This is a known reaction to a rapid **retreat of the grounding line** and can be interpreted as a consequence of the loss of basal friction, when parts of the glacier go suddenly fully or partially afloat.
- Our hypothesis is supported by a **change in the elevation change rate pattern**, whereby the **highest melt rates** can now be found at higher elevations **upstream of the new grounding line (see Map 6, Fig. 6a/b).** Furthermore, buoyancy calculations from OIB ice thickness data show that **the ice located more than 4 km upstream of the former grounding line now is free floating (see Map 6, Fig. 6b).** The localizations of the former and the new grounding lines are also in good agreement with **pinning points apparent in bedrock elevation data (see Fig. 6b).**
- The glaciers at Wordie Bay seem to be at **different stages** in their response to the loss of the former ice shelf. **Hariot West** glacier was **still influenced by the buttressing effect** of the remains of the former ice shelf and showed an acceleration after a major break up event in 2007 followed by a return to more stable velocities in 2015 **(see Fig. 4 left).** The **grounding line of Hariot East glacier is at a stable position since 1995 (see Map 2).**
  Fleming Glacier however has already to adapt to **new boundary conditions which are not solely connected to the disintegration of the former ice shelf anymore**. Instead **continuous oceanic melt and dynamic thinning at the grounding line** is very likely to have caused a big part of the glacier tongue to suddenly lift from its former pinning point **(see Fig. 6b**) and to go fully or partially afloat.

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